Model 20c	Porphyry Cu-Au
Alternative Model Name	
Commodities	Cu-Au-(Mo)
% Global Production	57% Cu; 8% Au
% Australian Production	Minor: mainly from Northparkes and Cadia (and Red Dome). [Cadia: 286 t g Au, 1,204,800 t Cu] [Northparkes: 69 t Au, 1,461,960 t Cu]
World Class Deposit Size	1000-13 000 Mt @ >0.5-2.5% Cu equiv (Cu +Au)
World Class Deposit Examples	Chiquicamata, Chile (>12 400 Mt @ 0.56% Cu) El Teniente, Chile (>8000 Mt @ 0.6% Cu) Los Pelambres, Chile (3300 Mt @ 0.63% Cu, 0.16% Mo) Bingham USA (3300 Mt @ >0.60% Cu, >0.34g/t Au, >0.053% Mo) Butte District, USA (7500 Mt @ >0.4% Cu La Escondida, Chile (1760 Mt @ 1.59% Cu, 0.27g/t Au) Lone Star, USA (6100 Mt @ approx 0.5% Cu) San Manuel-Kalamazoo, USA (1 Mt @ 0.74% Cu) Panguna, PNG (>1000 Mt @ 0.5% Cu) FSE (Phillipines (1423 Mt @ 0.4% Cu, 0.6g/t Au)
Geological Setting	Supra-subduction zone: • arc-arc, arc-oceanic plateau, and arc-continent collision settings • in island arcs and continental arcs • emplacement generally during regional compression but in some areas during periods of weak extension (Cerro Corona and Minas Conga in Peru), or within interarc rifts (Cagayan basin). Bingham emplaced during extension following prolonged compression (Sillitoe, 2000) • Localised changes to oblique convergence during overall orthogonal convergence (Corbett and Leach, 1998)
Age	Mesozoic to Tertiary dominant; known throughout Phanerozoic; few possible analogs in Archaean and Proterozoic.
Components:	
Source	Mantle source for calc-alkalic and alkalic magmas: may involve single, double or multi-stage melting of different source regions; metals mostly mantle source with a crustal contribution; volatiles (including water) - mantle source with probable crustal contribution
Transport/Pathway	Magmatic transport; usually within narrow tectonic corridors parallel to subduction zone; may be within lineaments oblique to subduction (eg strike-slip faults), or at high angles to subduction (e.g. transfer faults). But pre-, syn-, and post-accretionary deposits known from within individual terranes
Trap	Always at shallow crustal levels (upper 4 kms)- may involve volcanic architecture ie beneath volcanic edifices (e.g. stratavolcano) or in resurgent volcanoes, or be associated with high crustal level magma chambers with no associated volcanic edifice
Other	• Mineralisation is orthomagmatic; magmatic fluids critical for ore genesis, but interaction with other fluids (eg meteoric, seawater) important in forming characteristic alteration and metal zones • Decrease in magma flux associated with change/hiatus in tectonism may favour volatile generation • Metal-rich source regions may be important (e.g. Cu:Au:Mo ratios) • Volatile concentration and the timing of saturation, and rapid transport of magmas to high crustal levels may be equally important • Lower and mid-crustal magma chambers may act as mixing zones for magma batches and decrease potential

	• Early hornfels development or impermeable cap rock required to prevent major volatile, fluid and metal escape • Fractionation that leads to generation of a volatile-rich phase enriched in metals and permits volatile saturation; secondary boiling • Critical fluid variables include: bulk fluid composition, oxygen fugacity, sulphur content and fugacity, flux and volatile element contents (eg K, P, H_2O, CO_2, Cl, F, B), and depth of emplacement. These control the timing and nature of volatile saturation relative to the degree of fractionation and removal of comptible metals by crystallisation. Secondary boiling key process
Critical Elements	• I-type igneous intrusions of calc-alkaline to alkaline compositions; diorites, monzonites and monzodiorites; fluid and flux-element-enriched magmas • Characteristic alteration zoning in three dimensions around a central stock or multiple stocks and dykes. Zoning also in metals. Details of alteration and metal zoning dependent on magma composition (alkalic or calc-alkalic, and volatile and flux element content), wallrock composition, volatile disproportionation and local structures); classic early oxide phase with later sulphidation- often in several pulses • Intrusive geometries: multiple stocks and /or dykes most common: repeated structural focussing of magmas in one location; apophyses (e.g. cupolas) at the top of more extensive magma chambers • Textures: intrusive textures usually early equigranular intrusions followed by porphyry textured, with aplites; quartz veins: sheeted veins with phase separation in fluid inclusions; hydrofracturing of pre-existing intrusions and wall rock; intrusive and metasomatic (potassic) breccias • Mineralisation within or proximal to intrusions, (but range of other deposit types TYPICALLY form both adjacent to, and distal to source intrusions- ie through aqueous and/or vapour transport of metals and volatiles that escape through structural leakage zones/ or as a result of catastrophic volcanic processes)
Other Comments	• Au-rich deposits usually associated with more mafic magmas (diorite-monzonite), and with magnetite, and possibly emplaced at higher (<2 km) crustal levels • Au-rich deposits are commonly emplaced at shallow (1-2 km) crustal levels and hence are likely to be associated with coeval volcanic rocks (Sillitoe, 2000) • Many early production figures for porphyry deposits do not include Au (often not analysed) • Mo occurs with more felsic magmas • Many peripheral deposit types may be genetically associated with porphyry deposits. These include both high and low sulphidation Au-Ag(-Hg) deposits, Cu, Au, and Ag-Pb-Zn skarns, and Au-As-Sb replacement deposits and carbonate-base metal deposits, breccia pipe-hosted Au(-Cu) deposits and other carbonate replacement deposits, disseminated Au and Carlin-style Au deposits • Porphyry systems not conclusively demonstrated pre-Phanerozoic
Key References	Titley & Hicks, 1966; Lowell & Gilbert, 1970; Sillitoe, 1973, 1993, 1994; Gustafson & Hunt, 1975; Henley & McNab, 1978; Titley & Beane, 1981; Beane & Titley, 1981; Titley 1982, 1995; Sillitoe & Gappe, 1984; Solomon, 1990; Thompson, 1995;Williams & Forrester, 1995; McMillan & Panteleyev, 1995; Corbett & Leach, 1998.

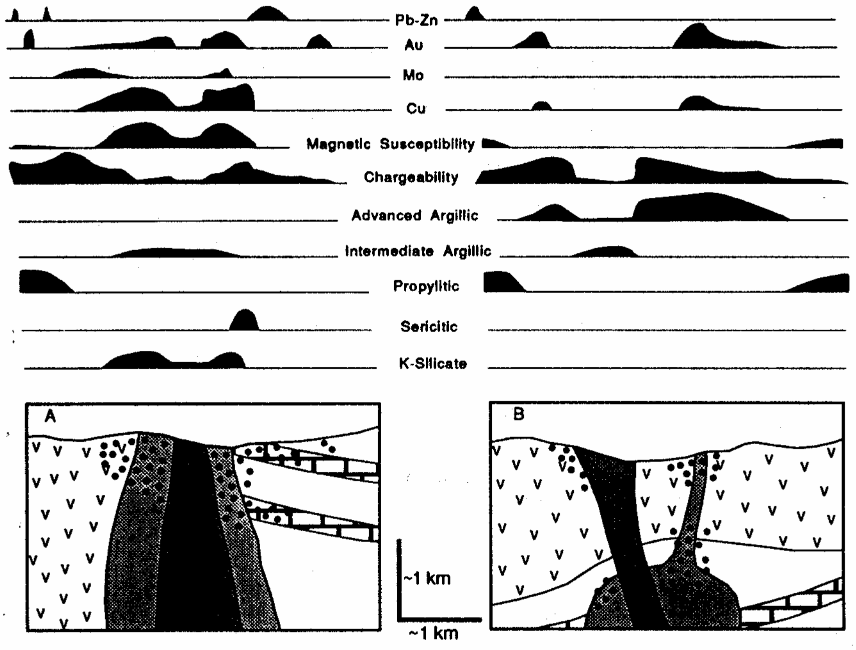


FIGURE 2. Schematic cross-section through two porphyry deposits. Each includes a complex intrusive centre, host rocks of different compositions, and zoning patterns based on alteration, geophysical signature and metal distribution. The deposits reflect different levels of erosion: (A) moderately eroded, and (B) minimal erosion. Diagrams are based on the models of Emmons (1927), Jones and Thompson (1991), and Sillitoe (1993).

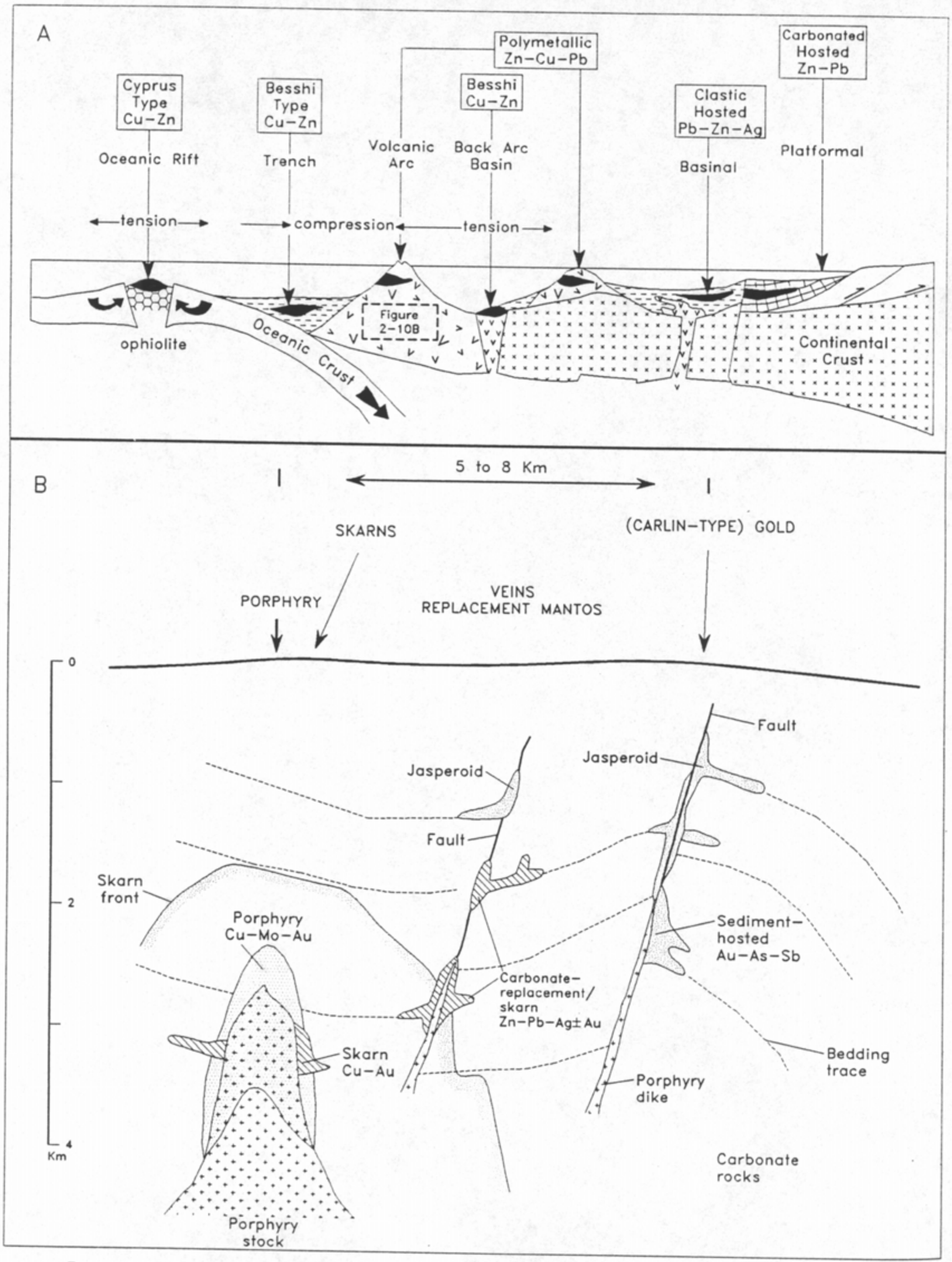
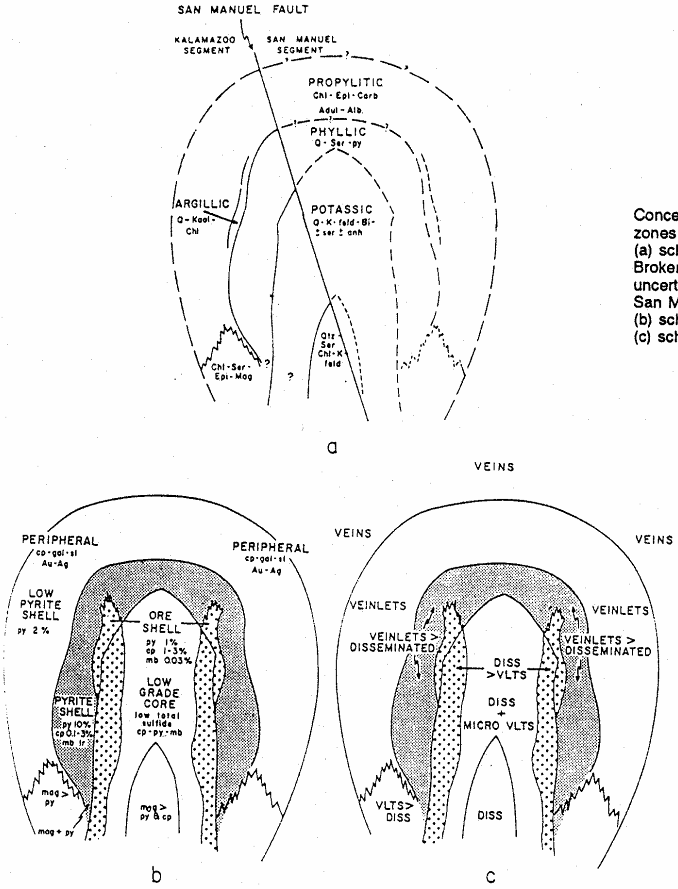
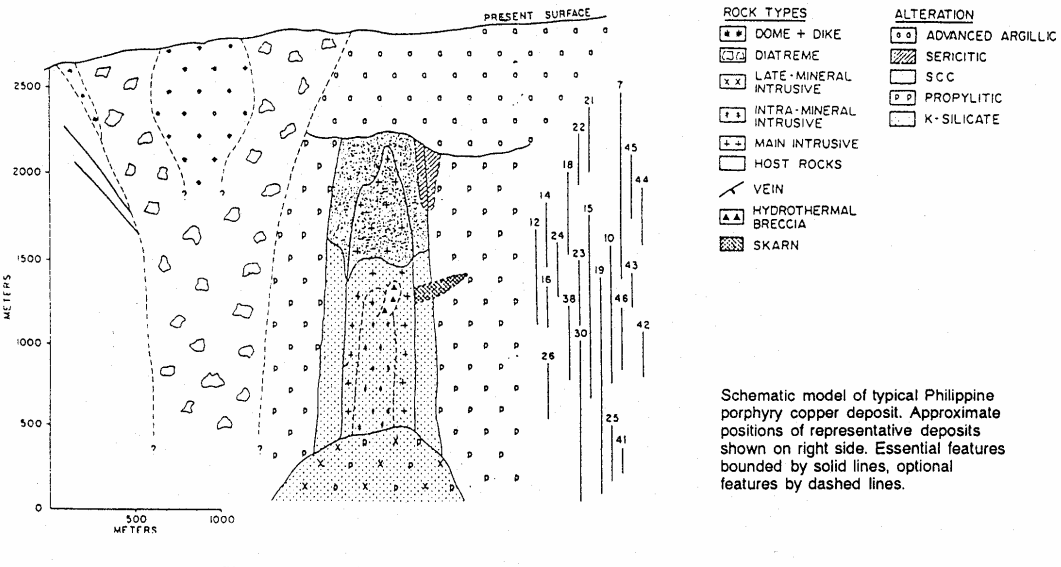


Figure 2-10. Schematic diagrams showing associations of mineral deposits with plate tectonic environments for (A) near surface volcanogenic massive sulphide, Sedex and platformal base metal deposits (modified after Hutchinson, 1980) and (B) subvolcanic porphyry, skarn, vein, replacement, manto and Carlin-type gold deposits (after Sillitoe and Bonham, 1990).



Concentric alteration-mineralization zones at San Miguel-Kalamazoo.
(a) schematic drawing of alteration zones. Broken lines on Kalamazoo side indicate uncertain continuity or location and on San Miguel side extrapolation from Kalamazoo.
(b) schematic drawing of mineralization zones.
(c) schematic drawing of the occurrence of sulphides.

Figure 35 Porphyry Copper Model from Lowell & Gilbert 1970



Schematic model of typical Philippine porphyry copper deposit. Approximate positions of representative deposits shown on right side. Essential features bounded by solid lines, optional features by dashed lines.

Figure 36 Philippine Porphyry Copper Model from Sillitoe & Gappe 1984